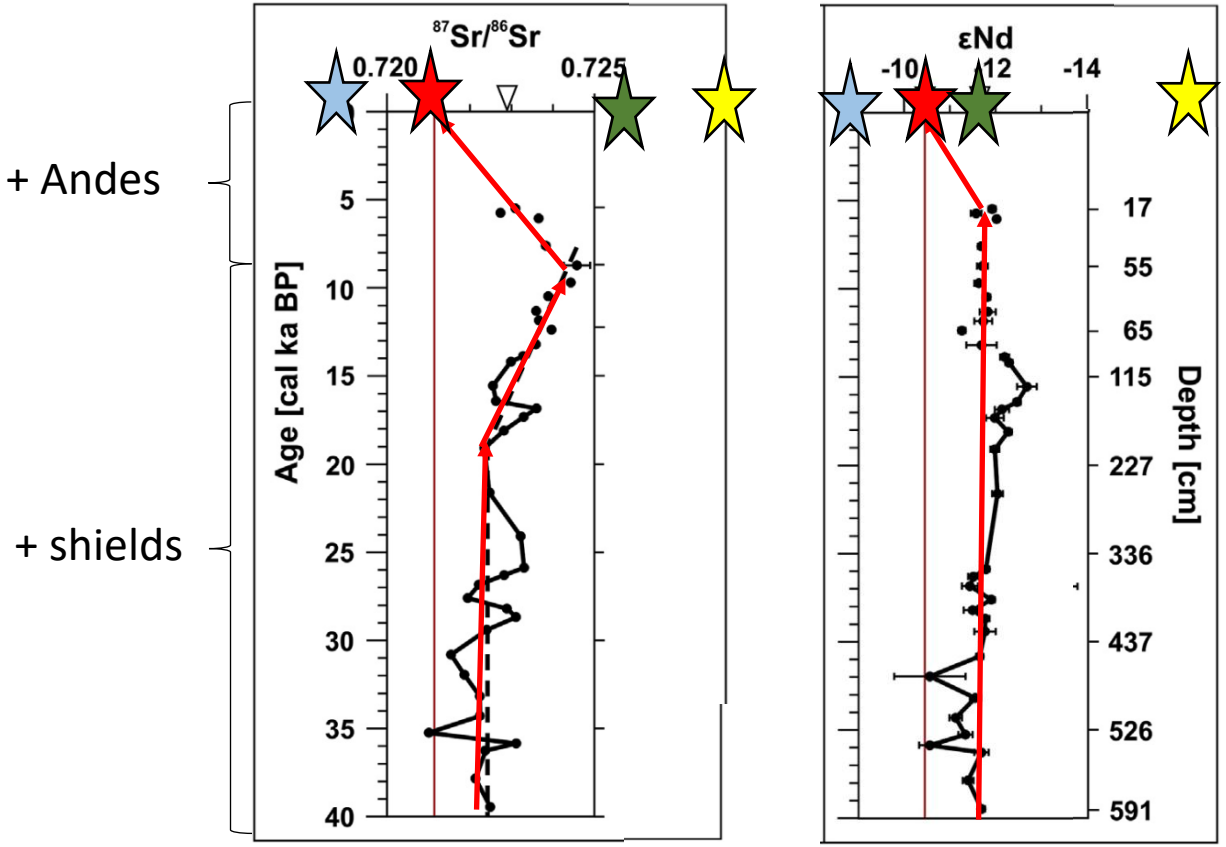
Seasonal variability of Sr and Nd isotopes in Amazon suspended matter as an analog for paleoclimate South American Monsoon System reconstruction

Jean-Sébastien MOQUET [1,2], Tristan ROUSSEAU [3], Martin RODDAZ [4], Julien BOUCHEZ [1], William SANTINI [4], Elisa ARMIJOS [5], Pascal FRAIZY [4], Roberto SANTOS VENTURA [6], Karina HATTINGH [6]

1 Institut de Physique du Globe de Paris - Centre National de la Recherche Scientifique - Sorbonne Paris Cité, France
2 Now at Institut des Sciences de la Terre d'Orléans, CNRS, Orléans, France
3 Universidade Federal do Ceara, LABOMAR, Fortaleza, Ceará, Brazil;
4 Géosciences Environnement Toulouse – Université de Toulouse – CNRS – IRD-OMP, 14 avenue Edouard Belin, Toulouse, France;
5 Instituto Geofisco del Peru, Lima, ;Peru
6 Laboratório Geochronos, Universidade de Brasília

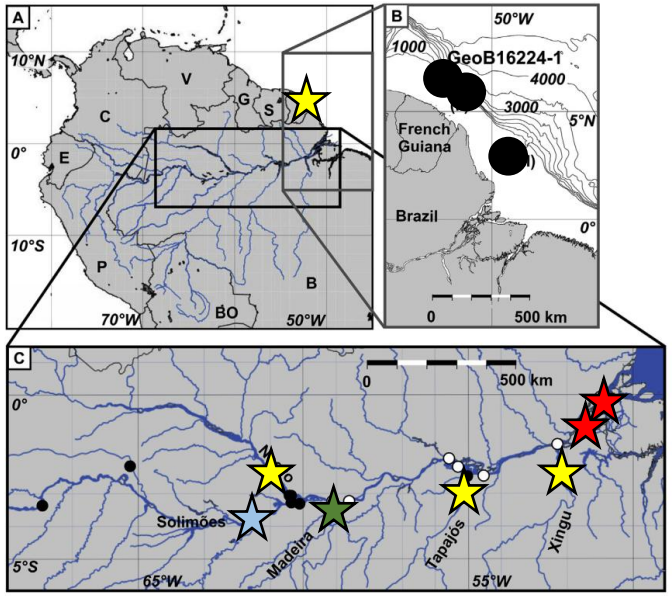
Sr and Nd radiogenic isotopes : conventional source tracers for paleoenviroment reconstruction



● Marine sediment cores

main tributaries **discrete sediments sampling** :

- Modern Amazon
- Madeira
- Solimoes
- Shields rivers



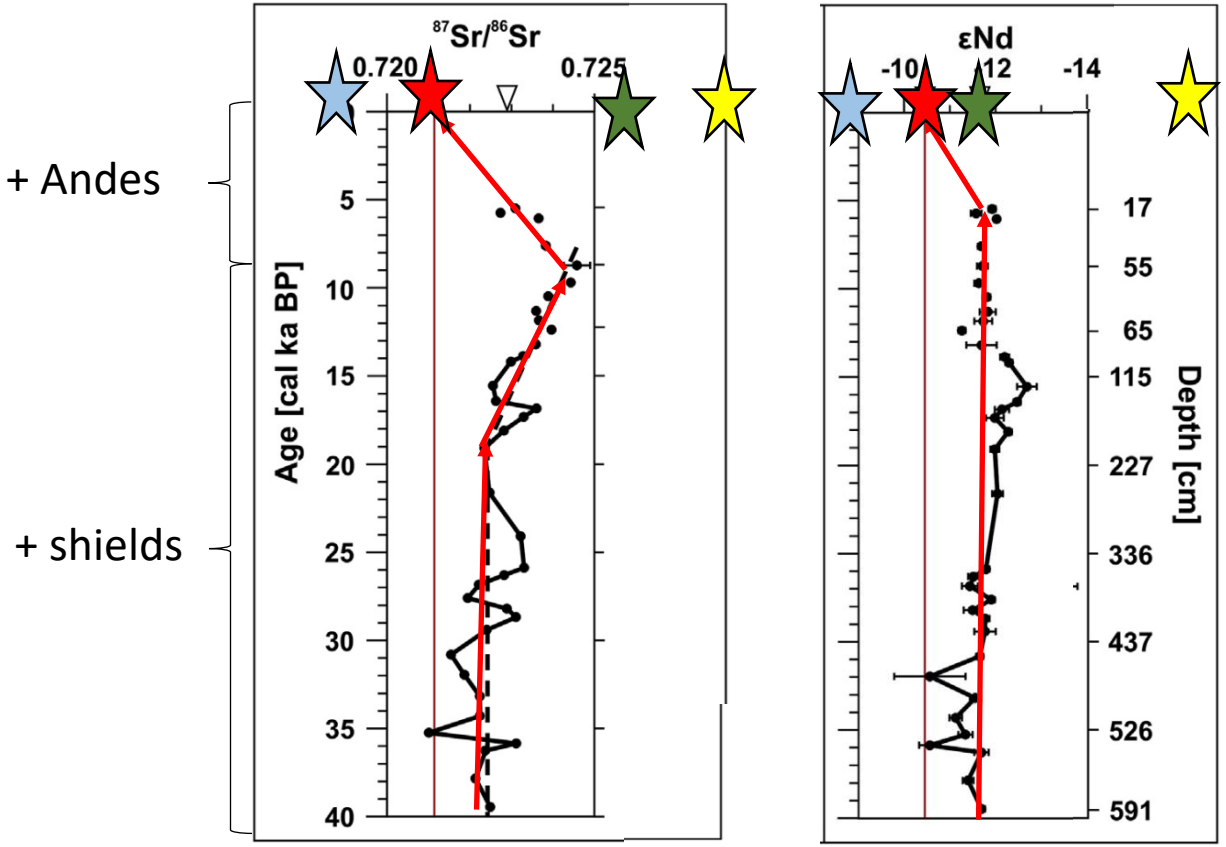
Hoppner et al., QSR, 2017

Along the last 40000 years :

→ Shift from shields to Andean sources

→ Decoupling of Nd and Sr isotopes

Sr and Nd radiogenic isotopes : conventional source tracers for paleoenviroment reconstruction



Along the last 40000 years :

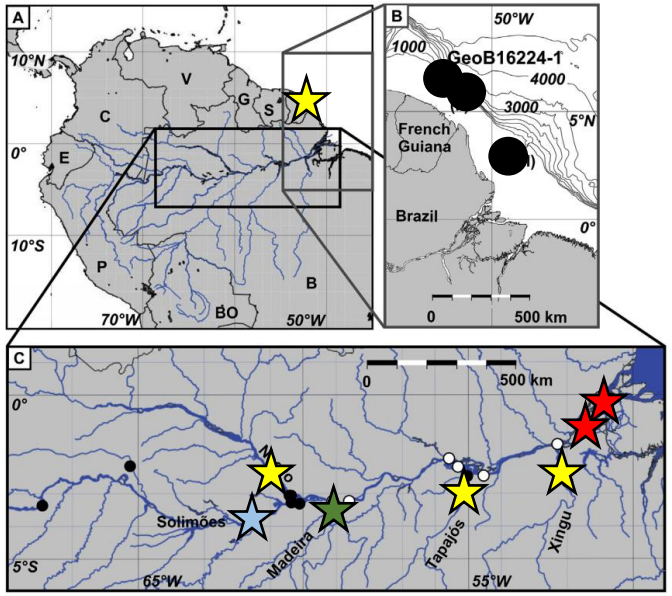
→ Shift from shields to Andean sources

→ Decoupling of Nd and Sr isotopes

● Marine sediment cores

main tributaries **discrete sediments sampling** :

- ★ Modern Amazon
- ★ Madeira
- ★ Solimoes
- ★ Shields rivers



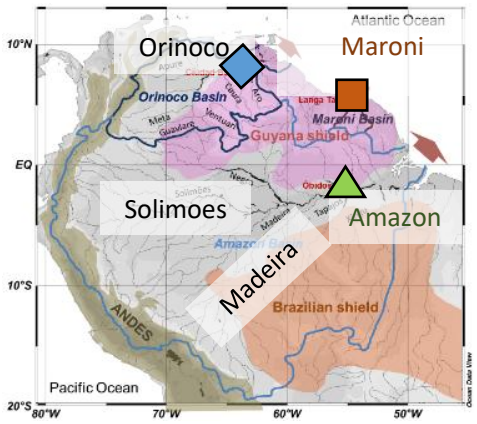
Hoppner et al., QSR, 2017

→ **Seasonal variability is rarely taken into account**

- Signature range
- Hydrological and hydrosediment behavior
- Identification of the floodplain effect

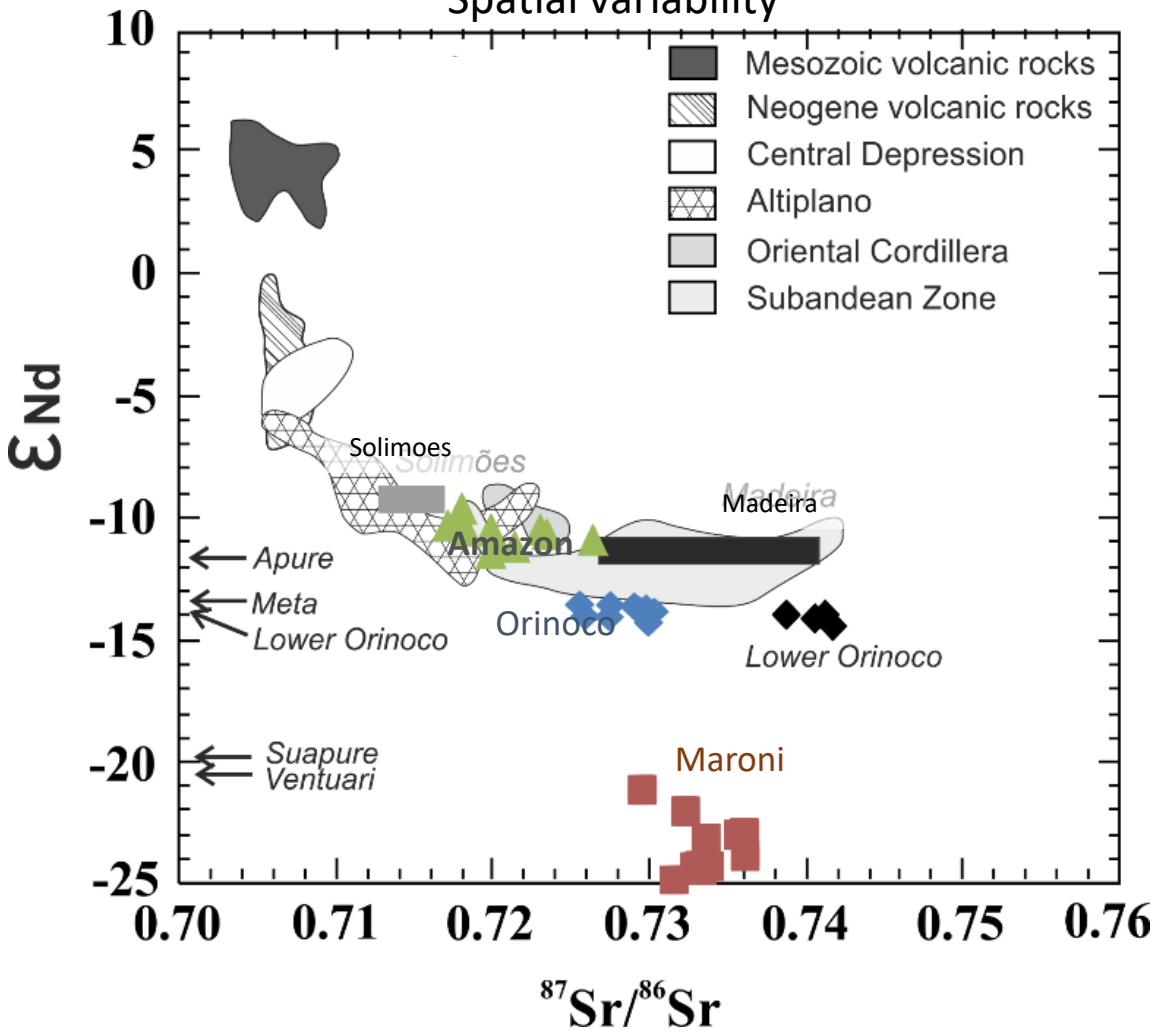
Sr and Nd signature of 3 south American rivers

Hybam sediment samples



Rousseau et al., Chemical Geology, 2019

Spatial variability



→ **Contrasted Nd and Sr isotopic signature**

→ Interpretation of marine sediment cores potentially influenced by these rivers/ environments

→ **Amazon = intermediate values between Madeira and Solimoes endmembers**

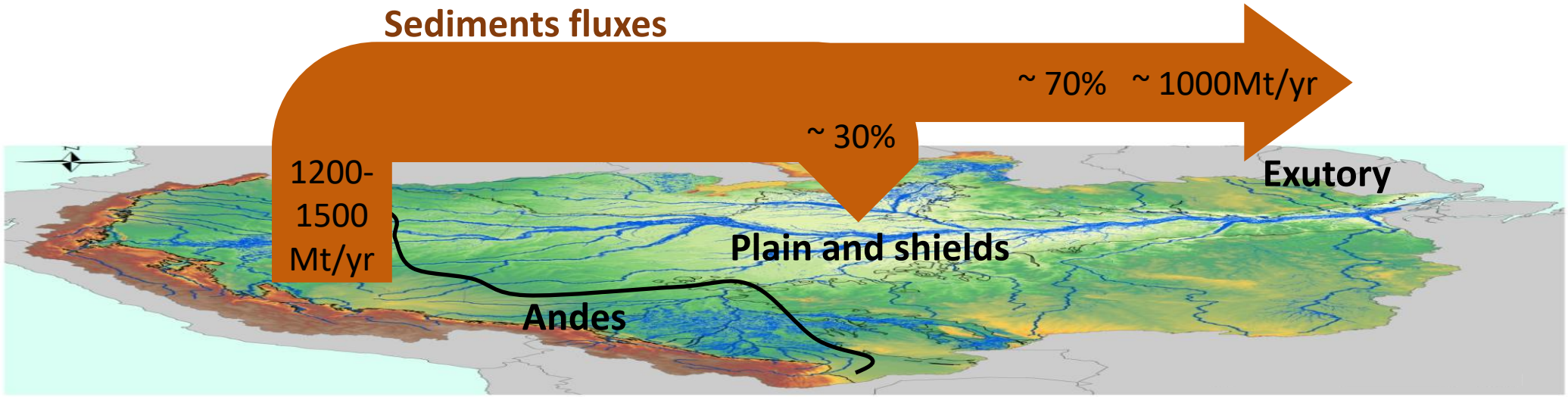
→ **Seasonal variability of Sr and Nd isotopic signatures**

Floodplain role in the sedimentary budget : geological and annual scale

Geological scale :

→ Before the Holocene : Floodplain under erosion = source of sediments *(eg. Irion et al., Hydrological Processes, 2009)*

Modern sedimentary processes (HYBAM sediments data):



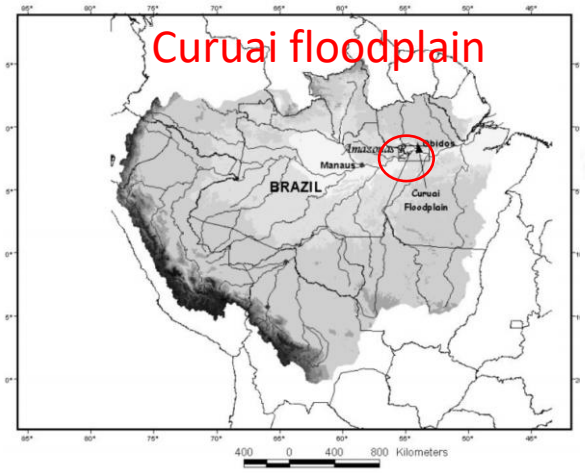
Filizola and Guyot, 2009; Armijos et al., 2013a, b; Guyot et al., 2011; Santini et al., 2015; Vauchel et al., 2017

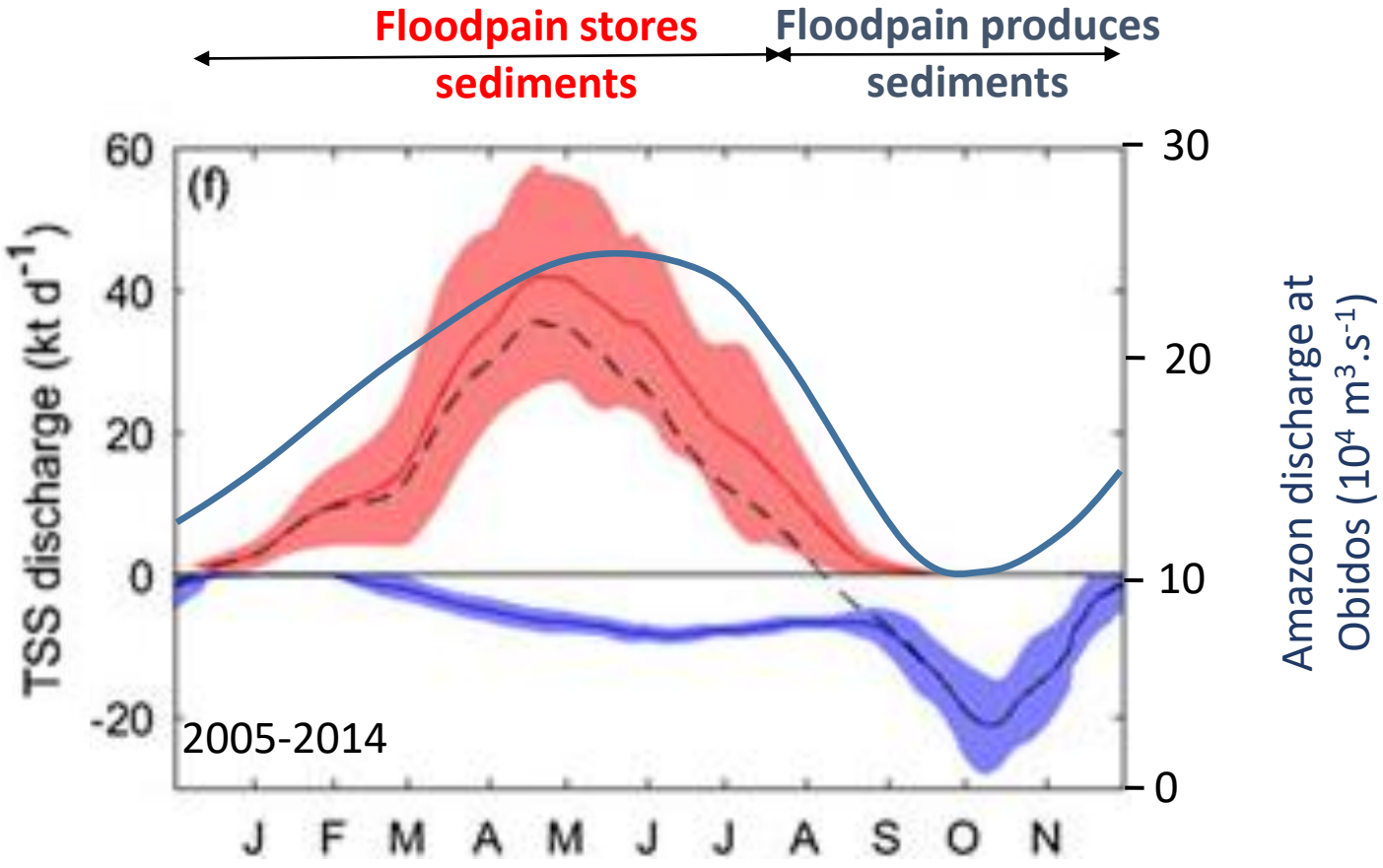
→ ~30% of the Andean sediments are deposited in the floodplain

→ the balance is not constant along the hydrological cycle

Floodplain role in the sedimentary budget : seasonal scale

Sediment budget of the Curuai floodplain

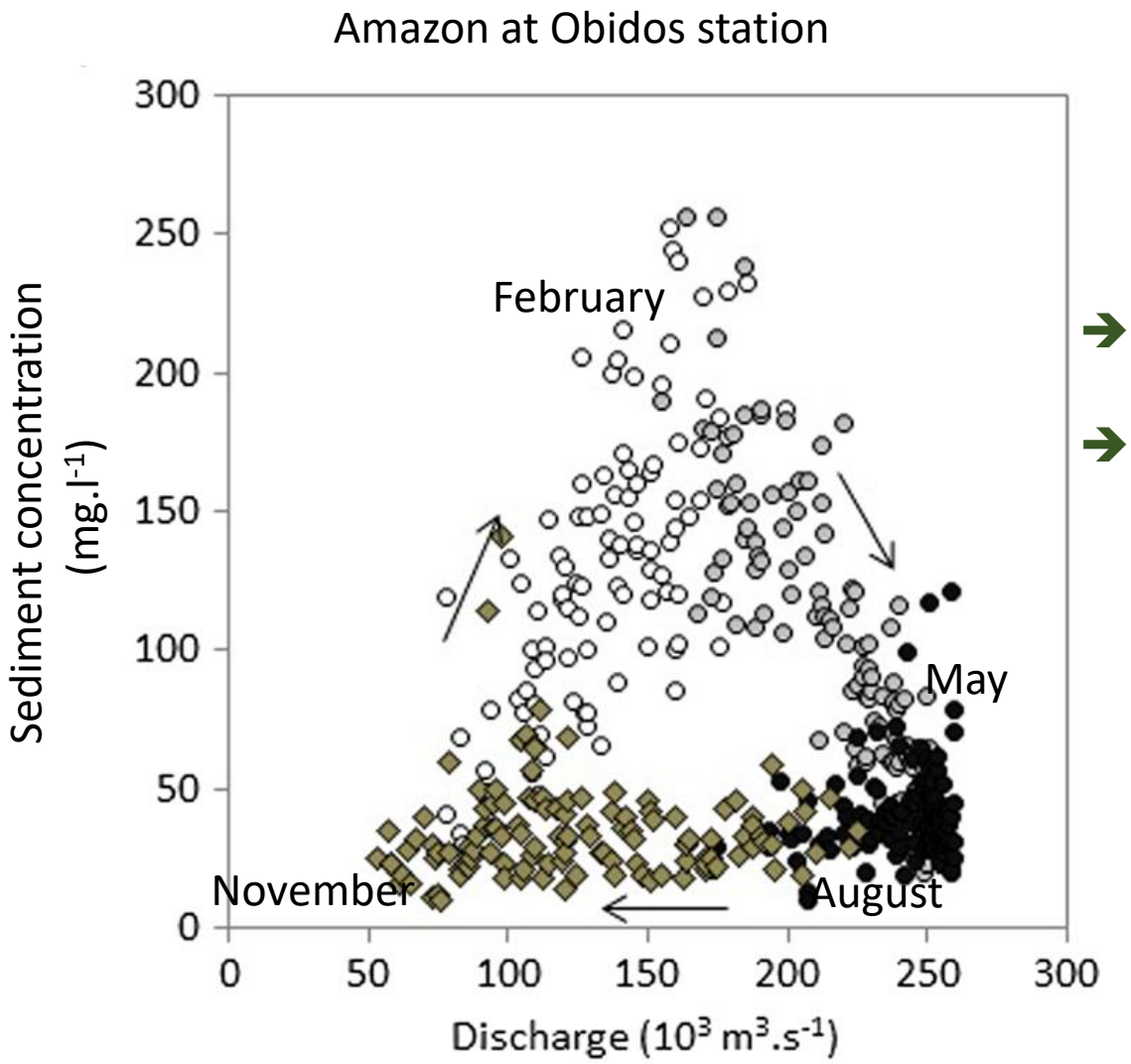




Maurice-Bourgoin et al., Journal of Hydrology, 2007
Ruddorf et al., Earth Surf. Process. Landforms, 2017

→ Floodplain can contribute to isotopes signature at the outlet

Amazon tributaries and floodplain control the sedimentary budget



- ➔ Offset of Solimoes vs Madeira vs Negro water and sediments inputs
- ➔ Floodplain storage/remobilsation

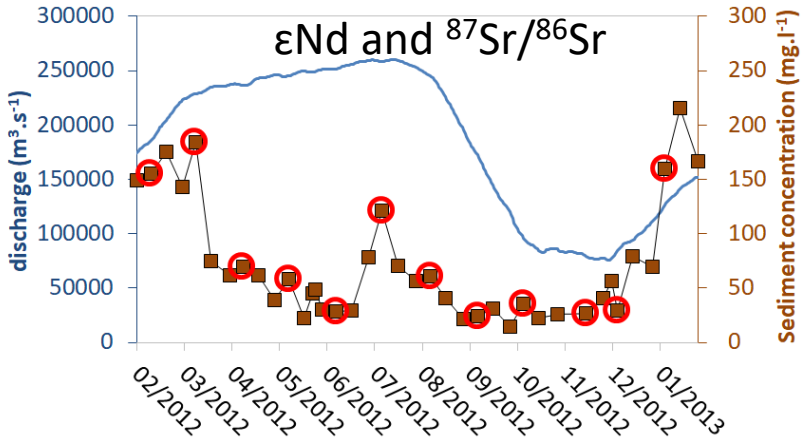
Dunne et al., GSA Bulletin, 1998; Guyot et al., IAHS, 2005; Martinez et al., Catena, 2009

→ How hydrology and sedimentology processes control the Nd and Sr isotope signature in the Amazon basin?

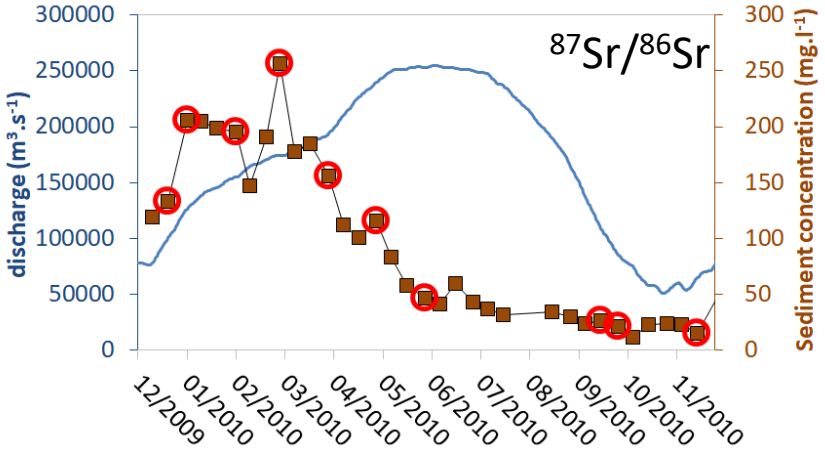
→ Effect on South American monsoon System reconstitution?

Material and method

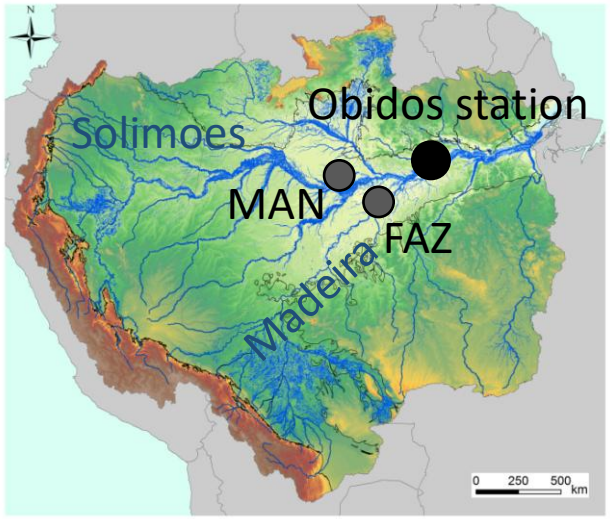
εNd and $^{87}Sr/^{86}Sr$ of the Amazon at Obidos



Rousseau et al., Chemical Geology, 2019



Hattingh, master thesis, 2014



Explaining factors :

Hydrosediments data (HYBAM)

- Daily discharge
- 10 days frequency sediments

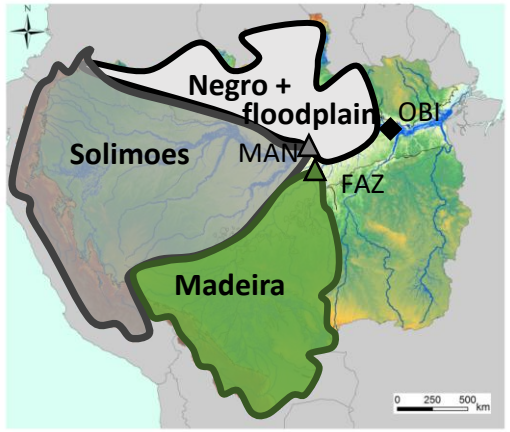
Geochemical data of Madeira and Solimoes

εNd and $^{87}Sr/^{86}Sr$ (Viers et al., EPSL, 2008)

➔ Calculation of fluxes : mass balance budget

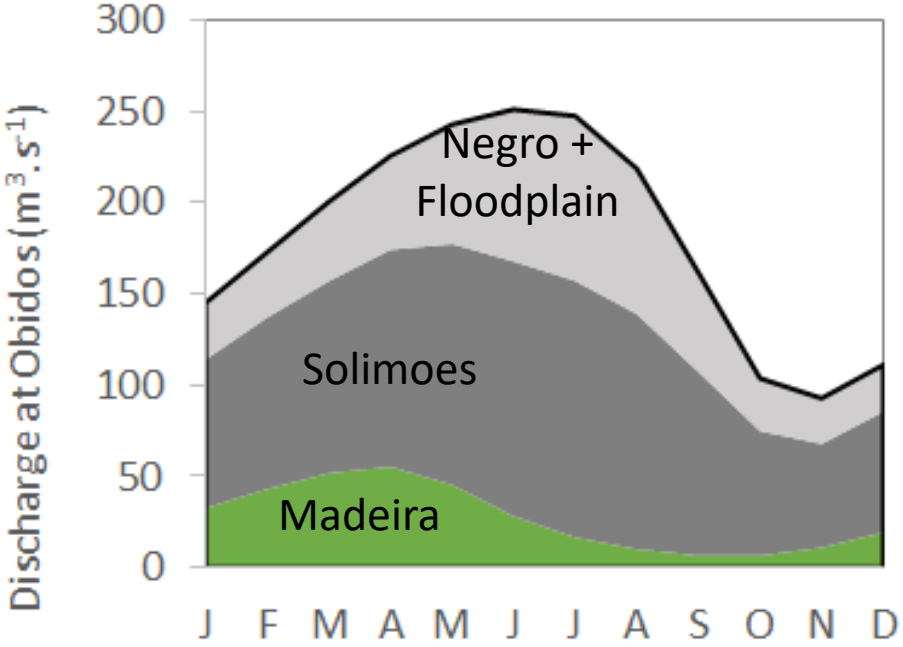
➔ **Solimoes / Madeira mixing model** vs **measured values at Obidos**

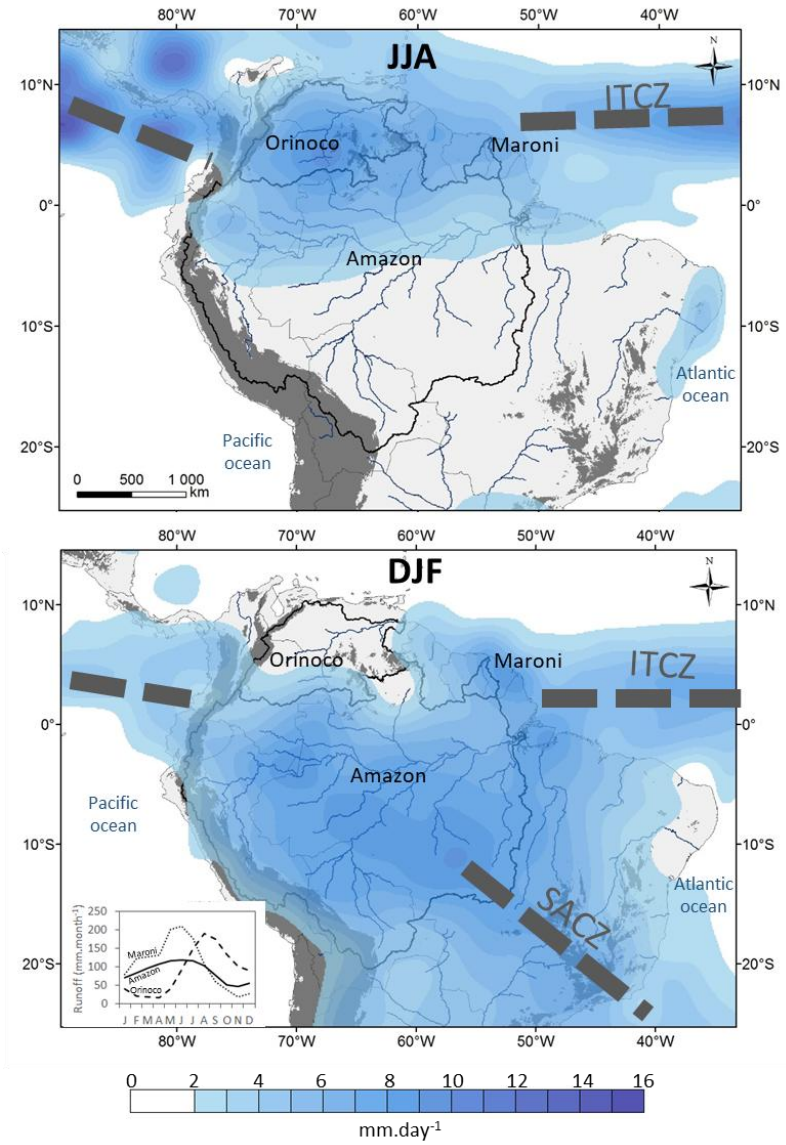
Hydrology at the Obidos station



Discharge

2003-2015 mean

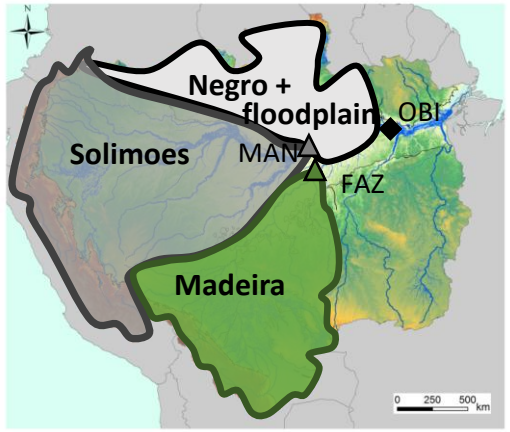




→ Discharge offset due to the ITCZ displacement

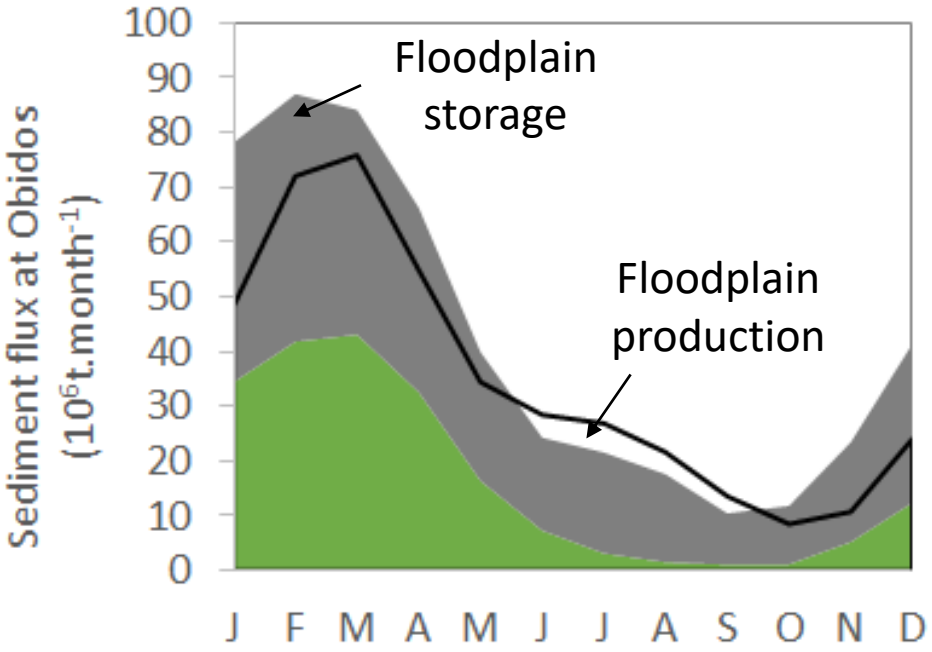
→ It would impact the Sr and Nd isotopes variability

Hydrology and sedimentlogy at the Obidos station



Hydrosedimentary budget

2003-2015 mean



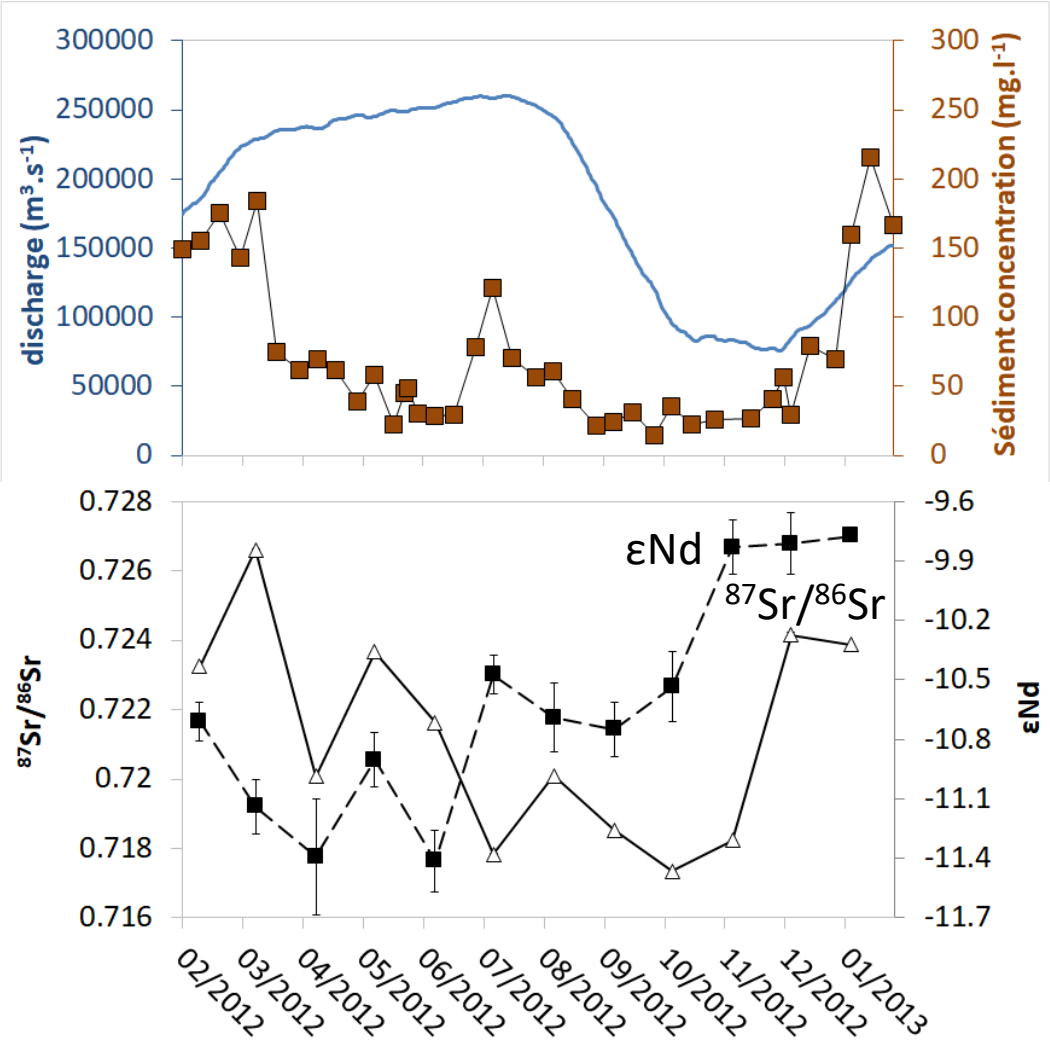
→ Negro sediment production = negligible (eg. Filizola and Guyot, HP, 2009)

→ We confirm the floodplain behavior observed at Curuai lake

→ Floodplain acts as a **sink** or as a **source** of sediment

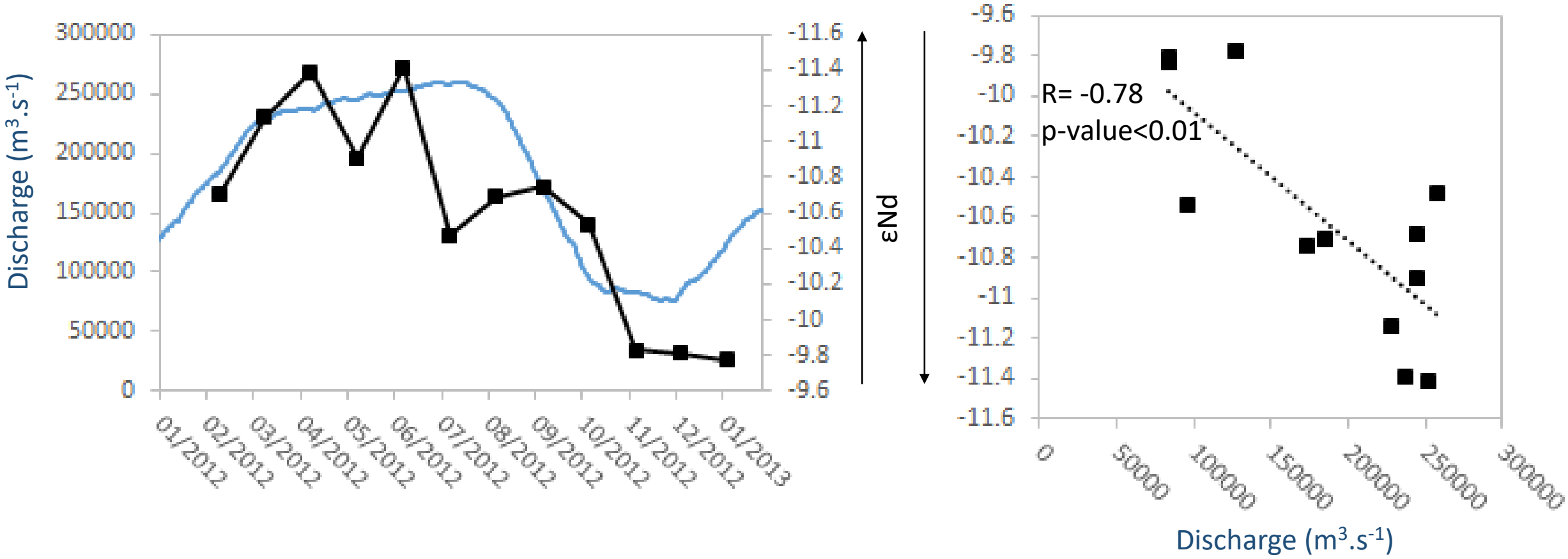
Sr and Nd behavior at Obidos station

Amazon at Obidos station



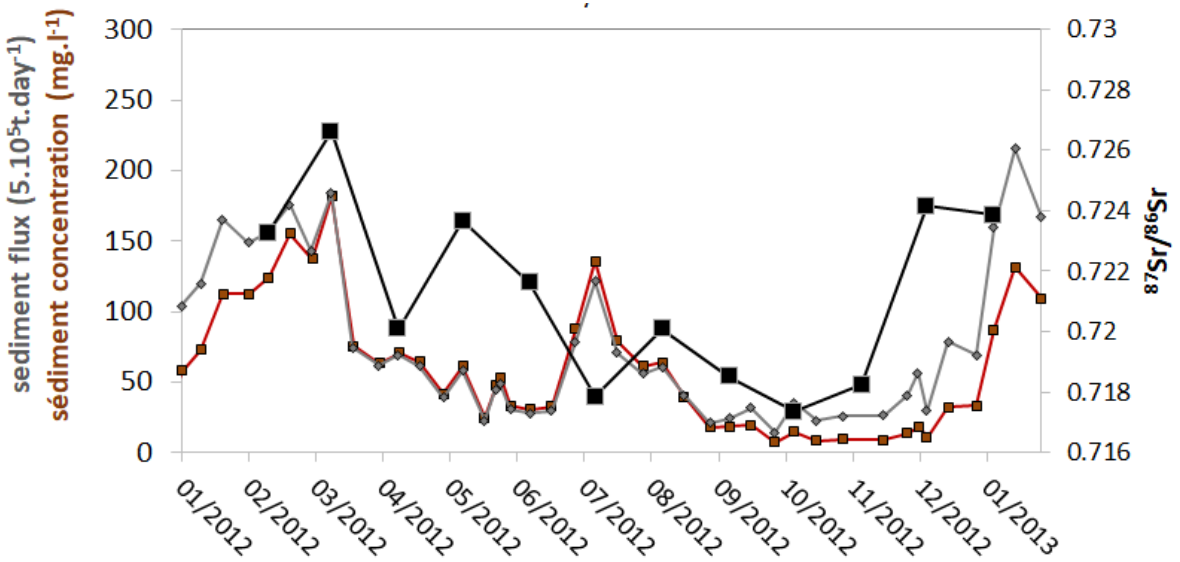
→ No direct significant co-variation between $^{87}Sr/^{86}Sr$ vs εNd

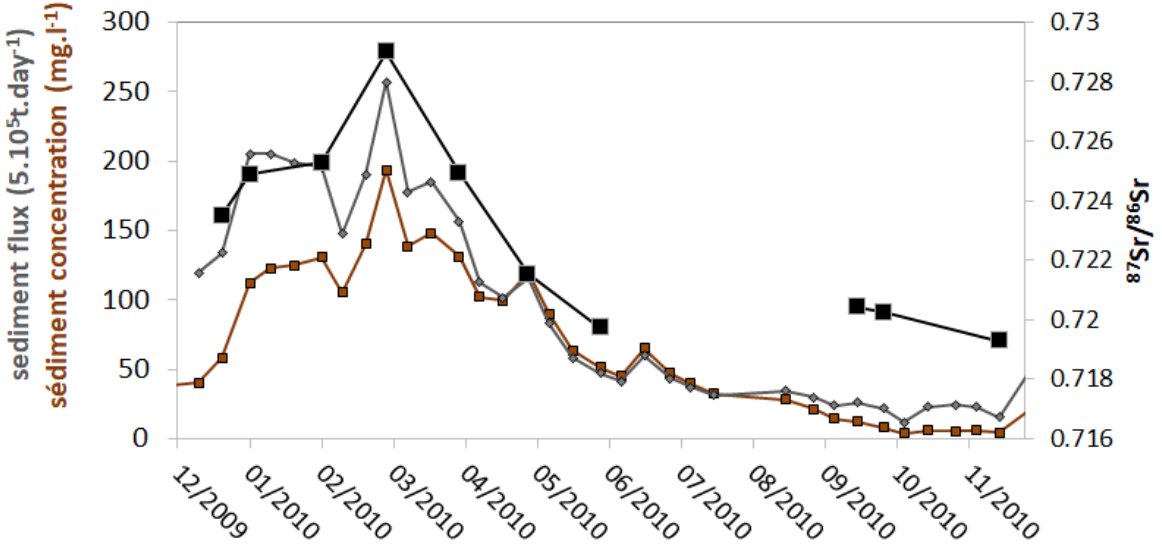
εNd behavior

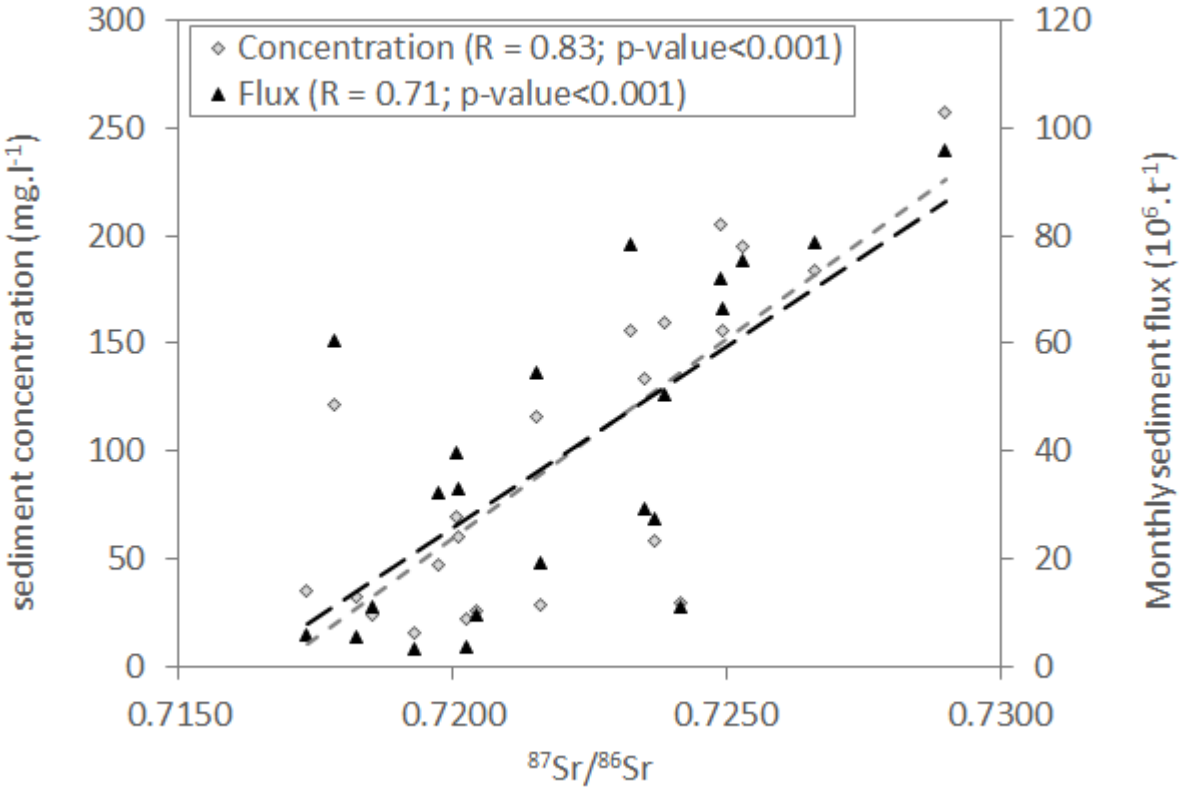


→ **εNd = a good direct proxy of the Amazon discharge variability**

$^{87}Sr/^{86}Sr$ behavior





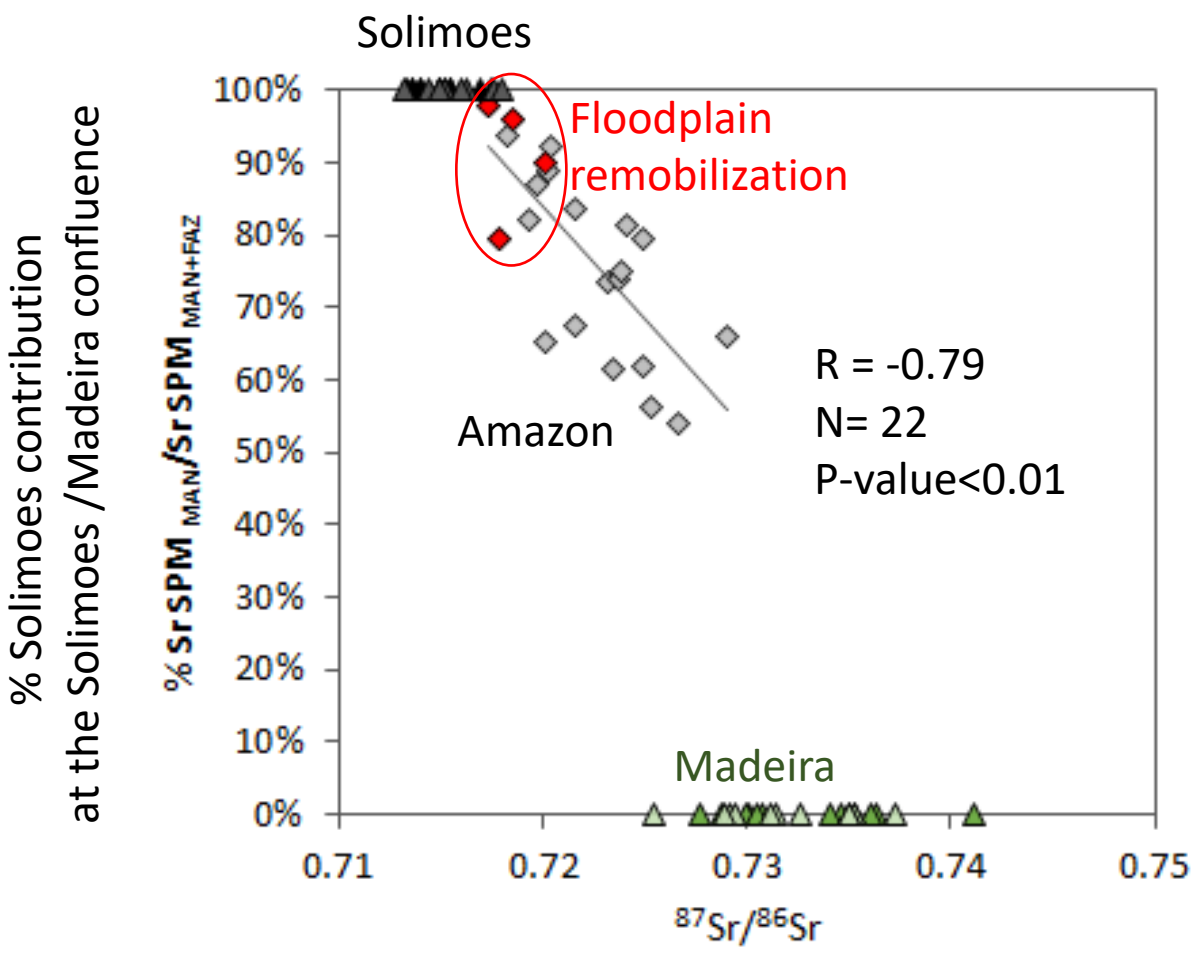


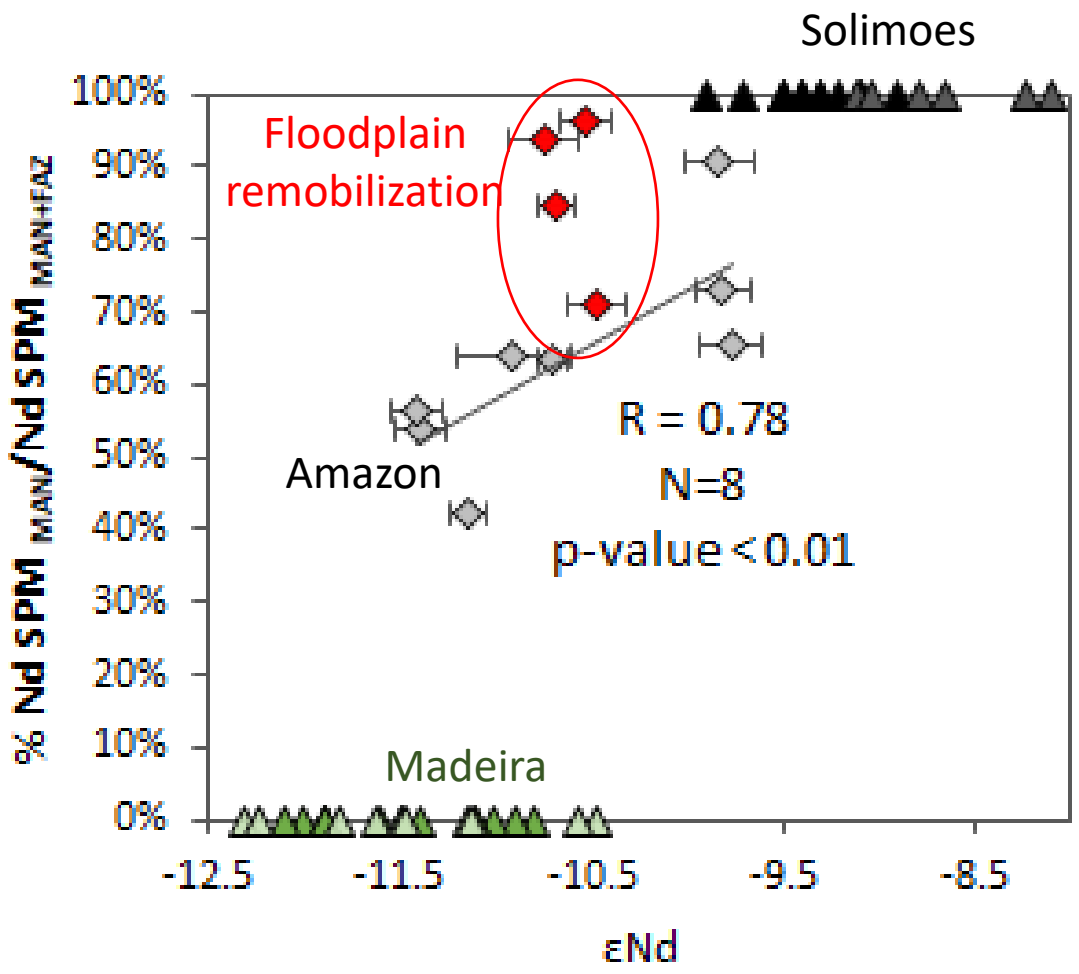
→ **Sediment flux variability mainly depend on sediment concentration**

→ **$^{87}Sr/^{86}Sr$ = proxy of the Amazon sediment production**

Mixing model

Nd and Sr isotope signature respond to a simple mixing model Solimoes vs Madeira





➔ Nd and Sr isotopes respond to a **simple mixing** behavior when floodplain is **neutral or is a sink of sediments**

➔ **When floodplain produce sediment → intermediate values of Nd isotopes**

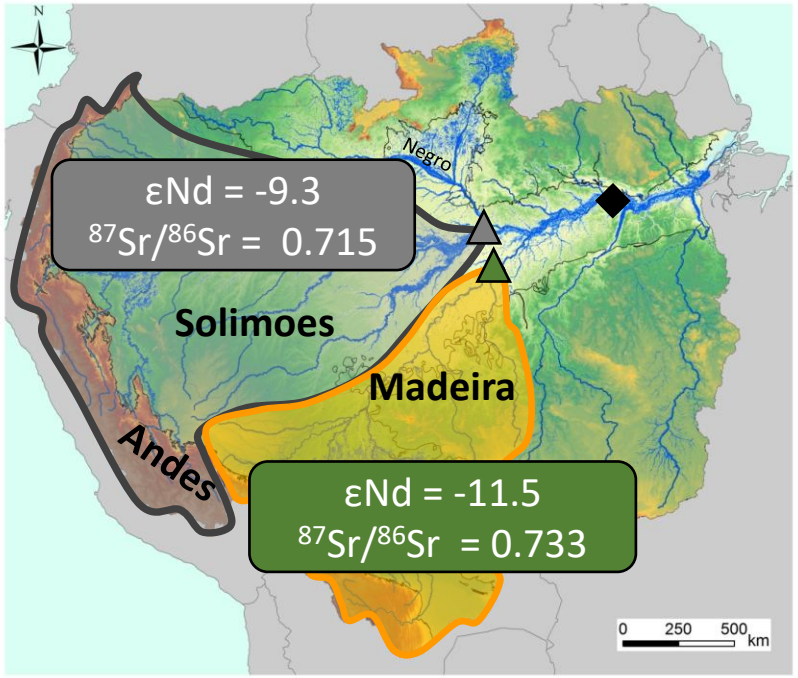
Solimoes vs Madeira mixing model

$$ {}^{a}X/{}^{b}X_{\text{Amazon}} = \frac{({}^{a}X/{}^{b}X \times X\ \text{Conc} \times \text{sed concentration} \times Q)_{\text{Solimoes}} + ({}^{a}X/{}^{b}X \times X\ \text{Conc} \times \text{sed concentration} \times Q)_{\text{Madeira}}}{(\text{Flux sed}_{\text{Solimoes}} + \text{Flux sed}_{\text{Madeira}})} $$

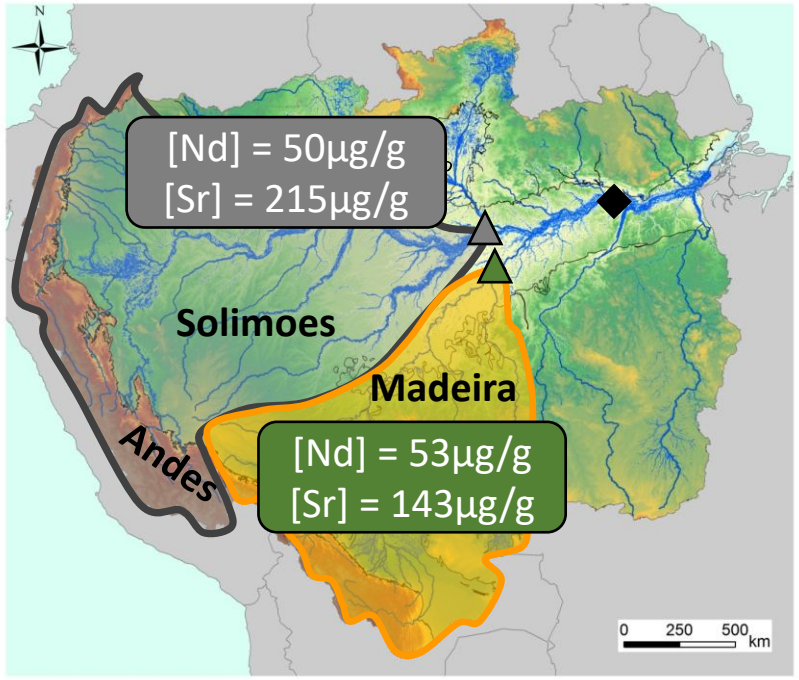
X = Nd or Sr

$$ {}^{a}X/{}^{b}X_{\text{Amazon}} = f({}^{a}X/{}^{b}X;\ X\ \text{conc};\ \text{sed conc};\ Q)_{\text{Solimoes vs Madeira}} $$

Mean isotopic signature



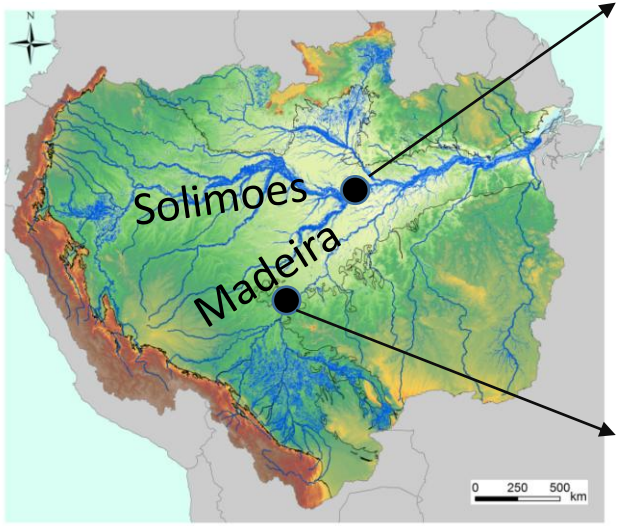
Mean concentration



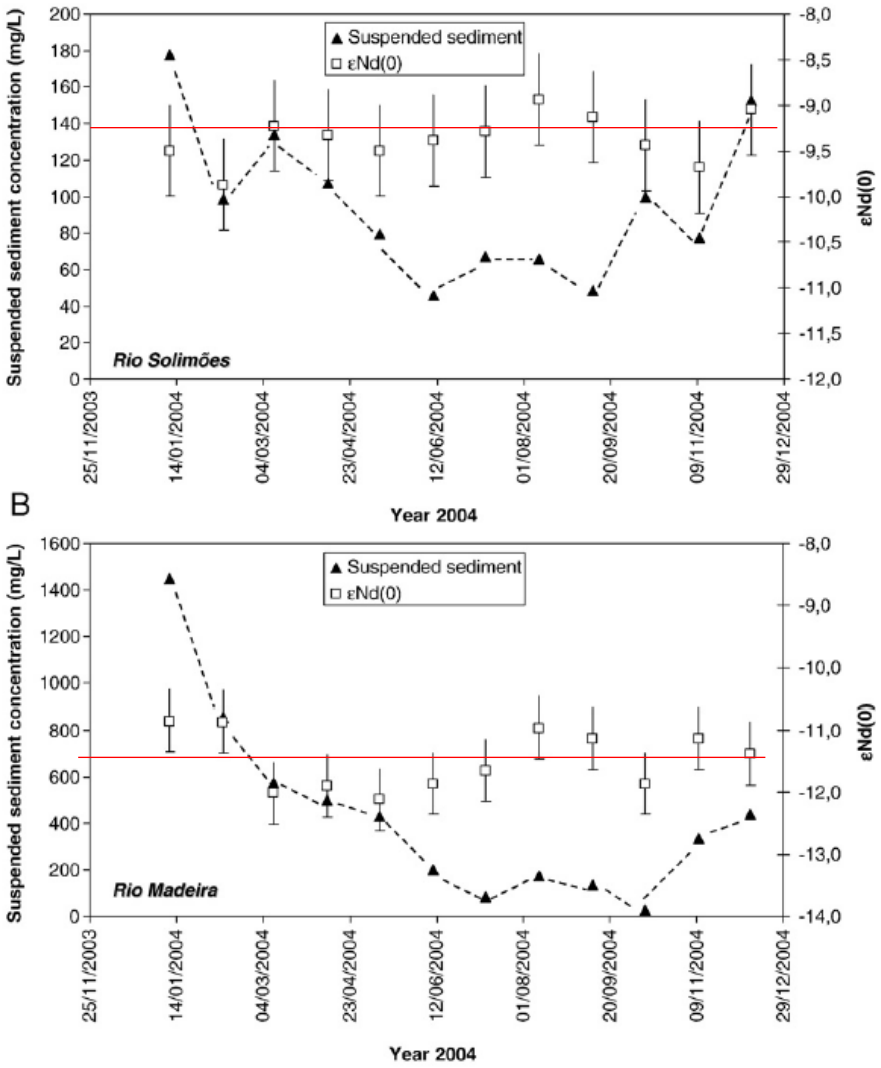
εNd and $^{87}Sr/^{86}Sr$ are contrasted

Nd concentration is homogenous
→ More sensitive to Q
Sr concentration is contrasted
→ More sensitive to sediment concentration

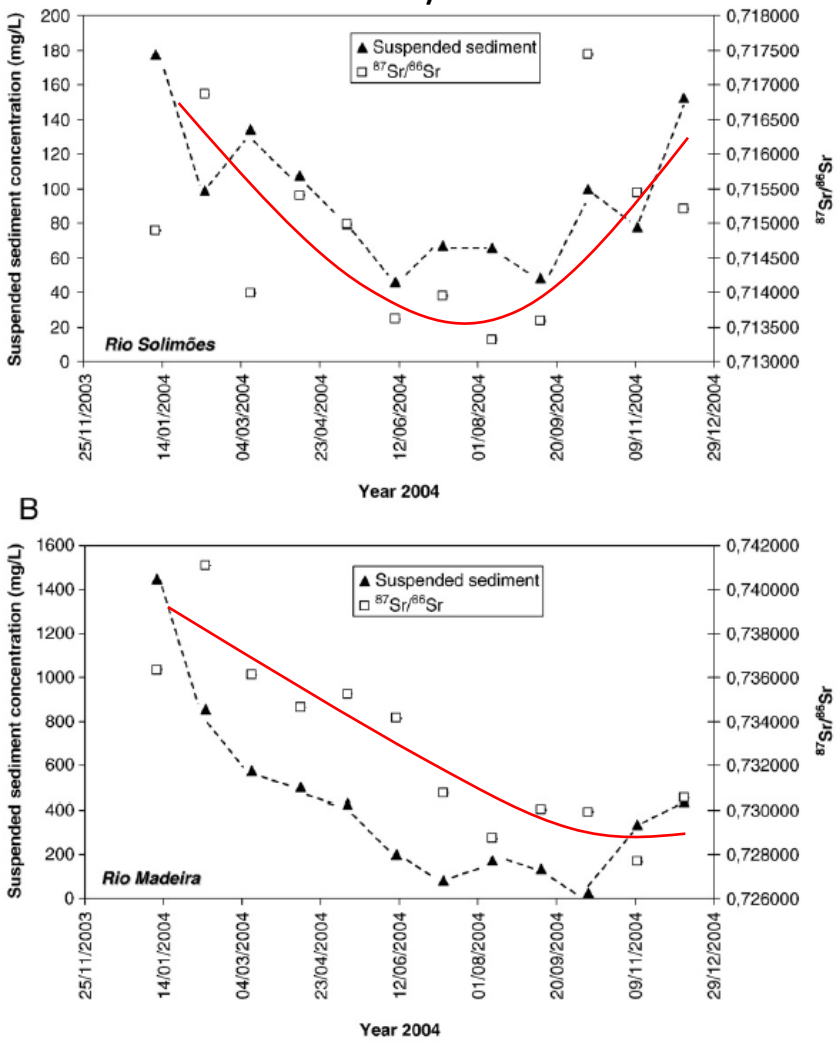
Solimoes vs Madeira mixing model



εNd



$^{87}Sr/^{86}Sr$



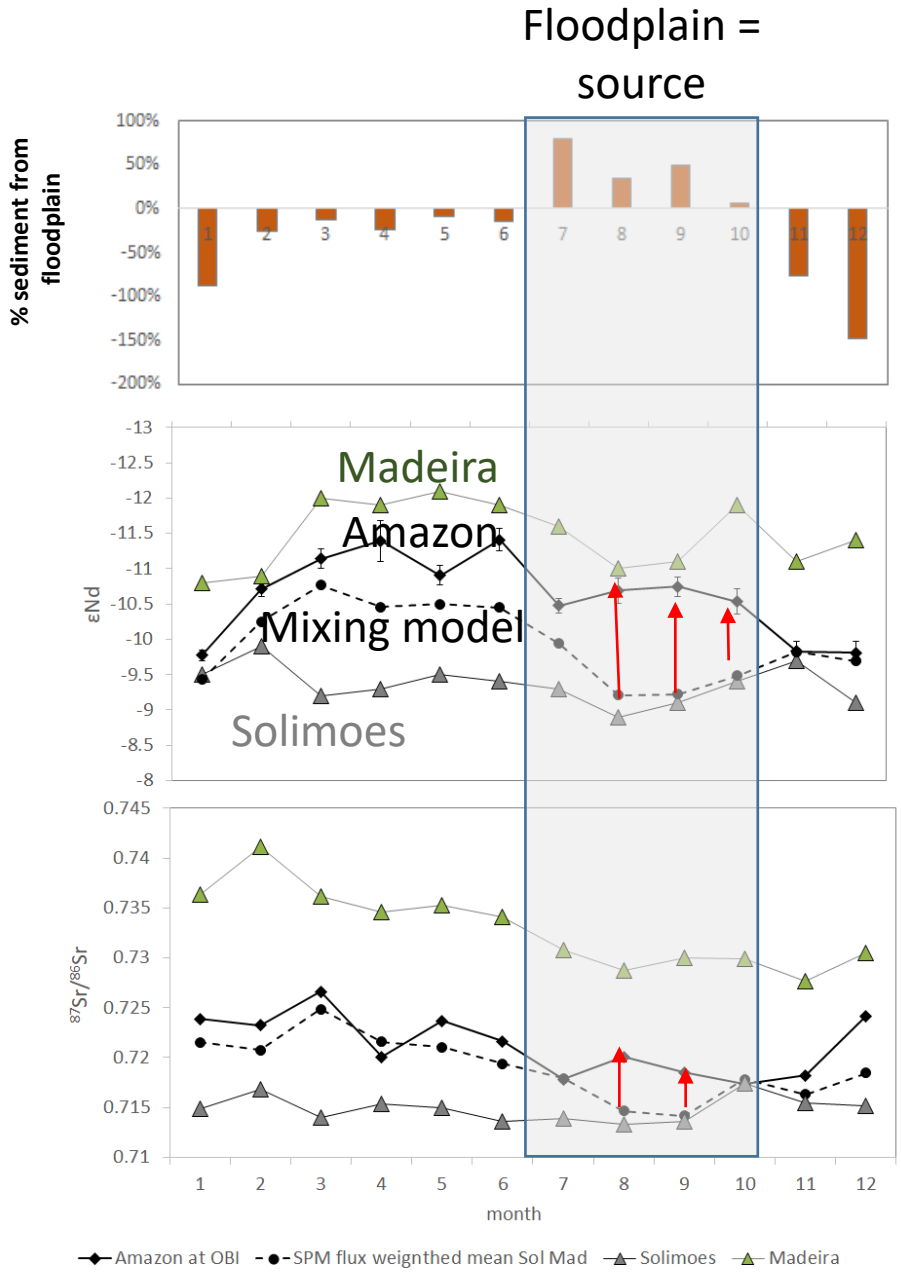
Viers et al., Chemical Geology, 2008

→ εNd is constant along the hydrological cycle

→ $^{87}Sr/^{86}Sr$ covaries with sediment concentration in the Madeira river

→ **This differences between explain εNd and $^{87}Sr/^{86}Sr$ decoupling at Obidos**

Floodplain contribution influence

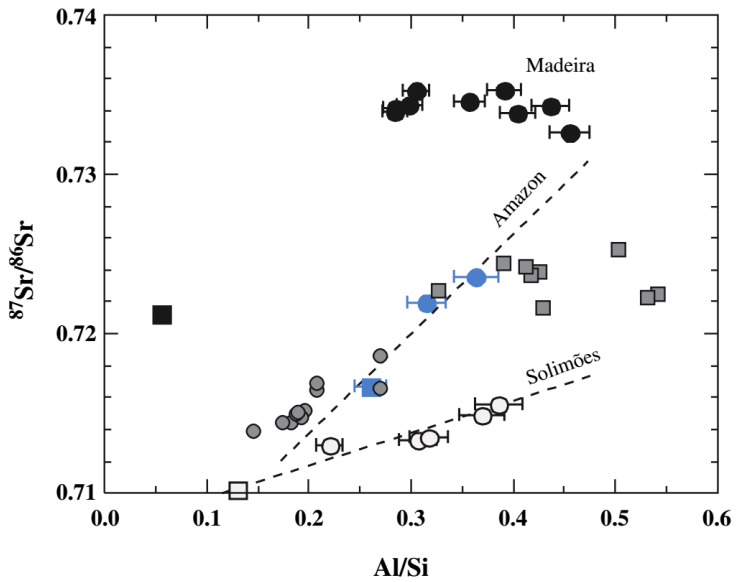


➔ When floodplain is **neutral** or is a **sink** of sediments

→ simple **mixing** behavior

➔ When floodplain **produce** sediments : Madeira influence more the sediment signature

→ Finer sediments, more easily removed from lake



Coarse ← Fine

Grain size

Bouchez et al., G3, 2011; Roddaz et al., Chem.Geol., 2014

Conclusion

Seasonal variation of εNd and $^{87}Sr/^{86}Sr$ at the outlet of the Amazon basin

εNd and $^{87}Sr/^{86}Sr$ are decoupled at the outlet of the Amazon basin

→ εNd co-varies with discharge
→ **Index of hydrological variability**
→ $^{87}Sr/^{86}Sr$ co-varies with sediment variability
→ **Index of erosion processes**

Solimoes /Madeira mixing model can explain it:
→ **homogenous Nd concentration** and **low seasonal** variability of **εNd** in Madeira and Solimoes
→ **Contrasted Sr concentration** and **high seasonal** variability of **$^{87}Sr/^{86}Sr$** in Madeira and Solimoes

Implication for Paleo-environment reconstitution
→ **When floodplain is neutral or a sink of sediment**
εNd and $^{87}Sr/^{86}Sr$ = Solimoes vs Madeira mixing model
tracers of oscillation, intensity (εNd), erosive activity ($^{87}Sr/^{86}Sr$) of the South American Monsoon system
→ **When floodplain is a source : grain size effect on sediment production**
→ **alter Sr and Nd isotope records**


Merci
Thank you
Obrigado
Gracias
Floodplain Ucayali River